Investigating tensile rate-dependence in composite laminates using a hydraulic pulse test bench

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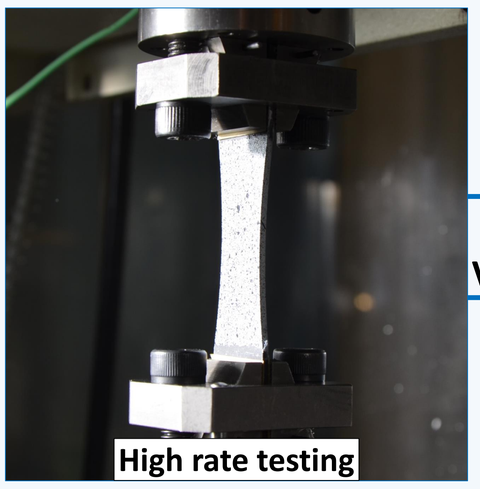
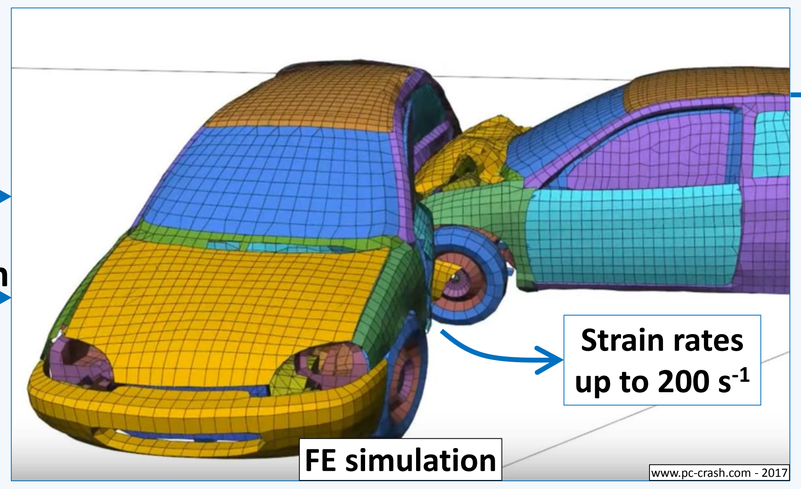
1. Motivation.

To meet the ever more stringent emission regulations, car manufacturers turn to composites to make lighter cars. Cost-effective manufacturing of structurally safe vehicles requires the use of FE-models to reduce testing: **accurate input test data at impact rates of strain** are needed.

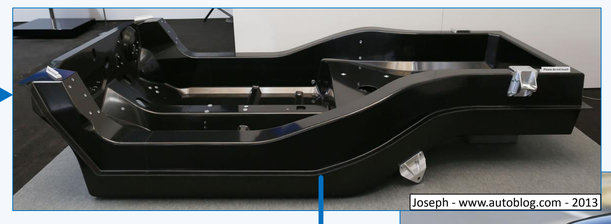


Input

Validation



Design



Far left: dynamic tensile specimen mounted in hydraulic pulse machine
Left: simulation of side-impact
Top: prototype CFRP chassis by Honda
Right: Honda CR-Z with CFRP chassis

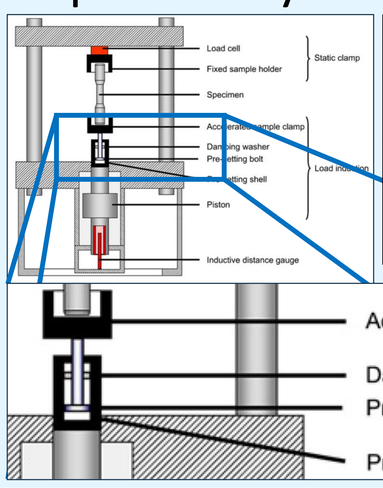
Composite car

2. Objective.

Obtain tensile properties of various composites from 10^{-4} to 10^{2} s^{-1} using a **single set-up**.

3. Method.

- **Hydraulic pulse test bench**: the only option to cover the full range of rates of interest
- A **slack rod** allows unloaded actuator speed-up
- Both **digital image correlation** and **strain gauges**
- A **piezoelectric** force sensor measures load
- Most challenging: the most brittle material at the highest speed of 15 ms^{-1}, this test lasts **20 µs**
- A minimum frequency of 25 kHz to be detected preferably above 250k samples/s



Schenck Hydropuls z25/20 VHS	
Clamp distance	0 – 1000 mm
Velocity range	0^{+} – 20 m/s
Load range	-25 – 25 kN
Measurement	• Load (piezoelectric cell) • Displacement • Strain (Vishay 2100)
Data acquisition	HBM Gen5i oscilloscope

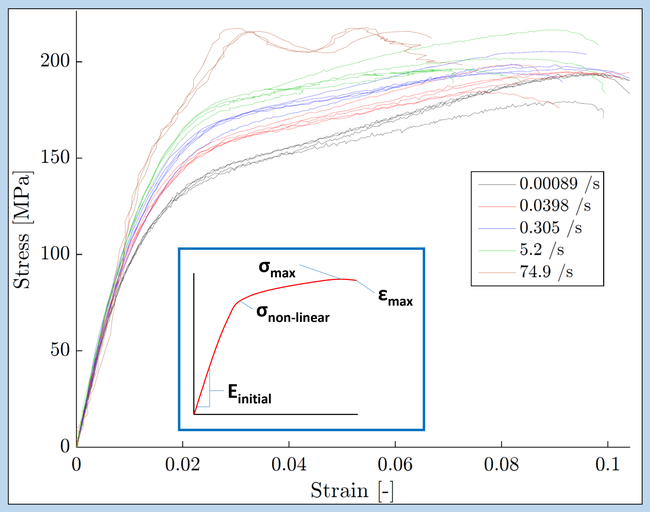
4. Materials. Two automotive composites.

- Carbon/epoxy (Mitsubishi Rayon & Honda R&D)
- Glass/PA-6 (Ten Cate Advanced Composites)

5. Results. Clear rate-dependency for #(±45):

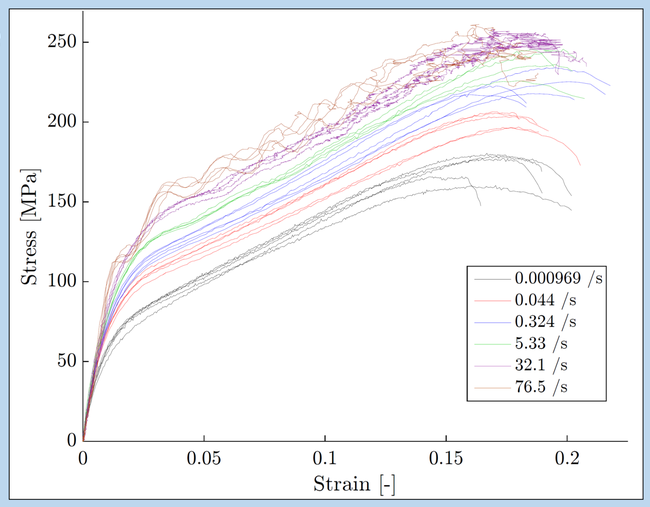
Carbon/epoxy plain weave
$[\#(\pm45)]_{4s}$ – thickness = 1.8 mm
Dogbone, L_{gauge} = 50 mm

Increasing rate:
- $\sigma_{non\text{-}linear}$: ↗
- σ_{max}: –
- ε_{max}: –
- $E_{initial}$: –



Glass/polyamide-6 twill weave
$[\#(\pm45)]_{2s}$ – thickness = 2.0 mm
Dogbone, L_{gauge} = 50 mm

Increasing rate:
- $\sigma_{non\text{-}linear}$: ↗
- σ_{max}: ↗
- ε_{max}: –
- $E_{initial}$: –



Conclusions:

Single hydraulic pulse machine suitable for tension in the range from 10^{-4} to 10^{2} s^{-1}
Discovered rate-dependence of thermoset- and thermoplastic-based composites
Highest achieved rate creates stress oscillations (inertia effects under research)

Improvements:

Load cell optimization: reduction of inertia effect
Specimen optimization: increase of maximum rate

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